A Rapidly Relocatable, Coupled Mesoscale Modeling System
for Naval Special Warfare

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LONG-TERM GOALS

The ongoing CMI RTP is designed to provide the full environmental spectrum of modeling support for NSW forces, by coupling the Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS), Navy Coastal Ocean Model (NCOM), and Simulating Wave Nearshore (SWAN) model. This capability offers a predictive capability of environmental parameters at scales on the order of 1 km, which is crucial for NSW operations. Testing is underway in the Battlespace Environments Institute to coupled COAMPS and NCOM utilizing the Earth System Modeling Framework (ESMF). A beta-test of the two-way coupled system is planned for FY07. It is anticipated that the two-way ESMF coupled air-sea system will be tested on the LINUX cluster (part of this project) and transitioned to the Navy through the Centralized Atmospheric Analysis and Prediction System (CAAPS) at FNMOC.

OBJECTIVES

Navy Special Warfare (NSW) operations are optimally supported by dedicated mesoscale atmospheric and oceanographic modeling responsive to temporal and spatial requirements. NSW forces operate and employ platform/vehicles, weapons, and sensors especially sensitive to the environment – both atmospheric and oceanographic. NSW operations are focused on small geographic areas for short duration. Rapid spin-up of globally relocatable models and production of model data to the forecasters over relatively short time frames is important. Mission analysis and execution benefit from high resolution atmosphere and oceanographic modeling that accurately characterizes and forecasts the battlespace and distributes the important information to NSW systems.

Utilizing the Naval Special Warfare Mission Support Center as a beta test facility, develop and implement modeling strategies for coupling atmospheric and oceanographic models and assimilation of METOC data from NSW sensors in near real time. This strategy will allow for operational support while at the same time providing a technology which can be scaled to larger systems and transitioned to Production Centers, i.e. FNMOC.

APPROACH

NRL is an established leader in the development of high-resolution atmospheric and ocean models, and air-ocean coupling. The atmospheric components of COAMPS™ (data quality control, analysis,

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initialization, and forecast model) have been operational at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) and at the Regional Centers since 1998. Since this time, COAMPS has established itself as a state-of-the-art mesoscale model, providing high-resolution (as low as 2 km grid spacing) guidance for many regions over the earth. In the past several years, considerable development has been done on building and testing the ocean components of COAMPS. We now have data quality control, a 3-dimensional multivariate optimum interpolation analysis, initialization, and forecast model components for the ocean. The ocean model is the NRL Coastal Ocean Model (NCOM), developed in the Oceanography Division at NRL Stennis Space Center (NRL SSC). NRL SSC is testing the relocatability of NCOM at various other geographic locations (e.g., East Asian Seas). NCOM (Barron et al, 2004) incorporates a database of monthly mean river discharge for more than 1000 rivers based on the work of Perry et al. (1996). Tidal forcing is provided by the Oregon State University (OSU) global tidal database (Egbert, et al., 1994; Egbert and Erofeeva, 2002). At each model timestep, the elevation and velocity due to the tide at the open boundary points are computed from the harmonic tidal constituent data by summing the contributions from each of the constituents. The total elevation and velocity at the open boundary points are then obtained by combining the values due to the tide with the elevation and velocity at the open boundary points obtained from global NCOM, which contain contributions from the non-tidal aspects of the ocean circulation. Global constituents are available at a 0.25° resolution and some regional areas (e.g., Mediterranean) have resolutions as high as 1/12°. Within a number of projects, NRL has demonstrated the need for high-spatial and temporal resolution fields for forcing an ocean model to describe the mesoscale phenomena typical of the ocean, the importance of data assimilation to adequately model air-sea processes, and the need for using unfiltered, native grid atmospheric fields to force an ocean model.

WORK COMPLETED

A 20-node LINUX cluster was installed at NRL-Monterey on August 15, 2005. The COAMPS-OS V1.2 was loaded onto the cluster with MVOI and the Navy Coupled Ocean Data Assimilation (NCODA). COAMPS consisting of a total of 4 nests (45/15/5/1.67 km) has been running twice daily for the Southern California area since September 28, 2005. An upgraded version of NCODA (MPI-3D) has been running on the cluster since January 2006. The MPI version can run on multiple processors.

The Navy Coastal Ocean Model has been set-up to run on the cluster on a daily basis producing 48-hour forecasts on the 00Z and 12Z watched utilizing the wind and surface forcing from the two inner-nests of COAMPS. A 5 and 1.7 km NCOM has been running daily since July 2006. The model is assimilating NOAA MCSST, GOES, ship, buoy and profile data.

COAMPS-OS wind fields are being ingested into the Distributed Integrated Ocean Prediction System (DIOPS), a wave, tide and surf prediction system running at the Mission Support Center, San Diego. NRL-SSC is investigating utilizing NCOM surface currents to be applied as boundary conditions to the FLOW component of Delft3D.

Work is underway to incorporate the nearshore wave model SWAN (Simulating Waves Nearshore) as part of the COAMPS-OS system. Plans include incorporating a SWAN "tab" within the COAMOS-OS GUI to facilitate model set-up and coordinate with the COAMPS model grid(s). A global WAVEWATCHIII model will be running on the cluster to provide boundary conditions (e.g., directional wave spectra) for SWAN.

RESULTS

Daily plots of the 4-nested San Diego COAMPS are available on project webpage (https://jaws.nrlmry.navy.mil , requires IP address to gain access). Graphical NCOM products are being developed. NCOM receives boundary conditions from Global NCOM run daily at NAVOCEANO. The Global model does not run until all the available NOGAPS forcing is available. This causes the NCOM run on the cluster to run later than desired. A temporary workaround has been to use forecast fields from global NCOM. Figure 1 depicts the anticipated two-way coupling between COAMPS and NCOM utilizing ESMF and a flux coupler. Data assimilation systems, and static databases provide the needed data for the atmospheric and ocean models. Sample products available from COAMPS-OS are shown in Figure 2. A sample NCOM graphics shown in Figure 3 depicts the sea surface temperature and currents for a 5 km NCOM region over southern California which is forced with 5 km COAMPS surface forcing.

IMPACT/APPLICATIONS

This project is laying the groundwork for future integrated METOC applications utilizing the ESMF. Nesting strategies are being developed and tested to ensure that a robust relocatable system can be transitioned to operations. The end user must be able to quickly set up a relocatable system for their area of interest. The GUI design strategy is to ensure that the end-user can easily setup the system quickly while maintaining fidelity in the ensuing products to support warfighter requirements.

NRL has is working with the NATO Undersea Research Center (NURC) on a Joint Research program on air-sea interactions. Members of this project attended an air-sea interactions workshop held in La Spezia November 29 – December 1, 2005 to discuss collaborative plans utilizing COAMPS-OS and the ensuing NCOM work and ESMF coupling. Opportunities to demonstrate system capabilities for Rapid Environmental Assessment during sea trials show much promise.

TRANSITIONS

It is anticipated that the software developed in this project will be transitioned to CAAPS at FNMOC beginning in FY08.

RELATED PROJECTS

Development and Evaluation of Ocean Model Relocatability in Air-Sea Coupled Models [PI: Allard – NRL Base 6.2] developing the appropriate global data bases for bathymetry, boundary conditions, initial conditions, tidal and riverine forcing, the associated extraction software, and the automated grid-generation software for setting up and running a relocatable NCOM system.

Battlespace Environments Institute (BEI) [PI: Allard, Campbell – CHSSI 6.3] developing Earth System Modeling Framework versions of Navy numerical codes (e.g., ADCIRC, COAMPS, HYCOM, NCOM, SWAN) and developing coupled applications (e.g., HYCOM-CICE, COAMPS-NCOM) to address air-sea interactions.

Small Scale Oceanography [PI: Rowley – 6.4]: the development and transition of an ocean nowcast/forecast capability for coastal regions and semi-enclosed seas. The system will be run on both CLASS and UNCLASS systems.

East Asian Sea [PI: Riedlinger – 6.4]: The East Asian Seas (EAS) model is a regional application of the Navy Coastal Ocean Model (NCOM) in the Western Pacific (WESTPAC). The EAS model domain includes the South China Sea, the East China Sea, the Yellow Sea and the Japan/East Sea. This model was developed by the Naval Research Laboratory (NRL) as part of a forecast system to predict ocean currents, temperature, salinity and elevation for the WESTPAC region. A validation report for EAS was completed during FY06, the system is anticipated to be transitioned to NAVOCEANO in FY07. http://www7320.nrlssc.navy.mil/EAS16_NFS/ .

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Barron, C.N., Kara, B.A., Rhodes, R.C., Rowley, C. and Smedstad, L.F., 2004: Validation Test Report for the 1/8o Global Navy Coastal Ocean Model Nowcast/Forecast System.

Egbert, G.D., A F. Bennett, and M.G.G. Foreman, 1994: TOPEX/Poseidon tides estimated using a global inverse model. *J. Geophys. Res.,* **99**, 24821–24852.

Egbert, G. and L. Erofeeva, 2002: Efficient inverse modeling of barotropic ocean tides. *J. Atmos. Oceanic Technol.*, **19**, 183-204.

Perry, G.D., P.B. Duffy, and N.L. Miller, 1996: An extended data set of river discharges for validation of general circulation models. *J. Geophys. Res*., **101**, 21339-21349.

HONORS/AWARDS/PRIZES

2005 NRL Review Directorate Award for paper "A Real-Time Coastal Ocean Experiment" in which the relocatable NCOM system was utilized during the Maritime Rapid Environmental Assessment Trial off of Portugal in 2004.
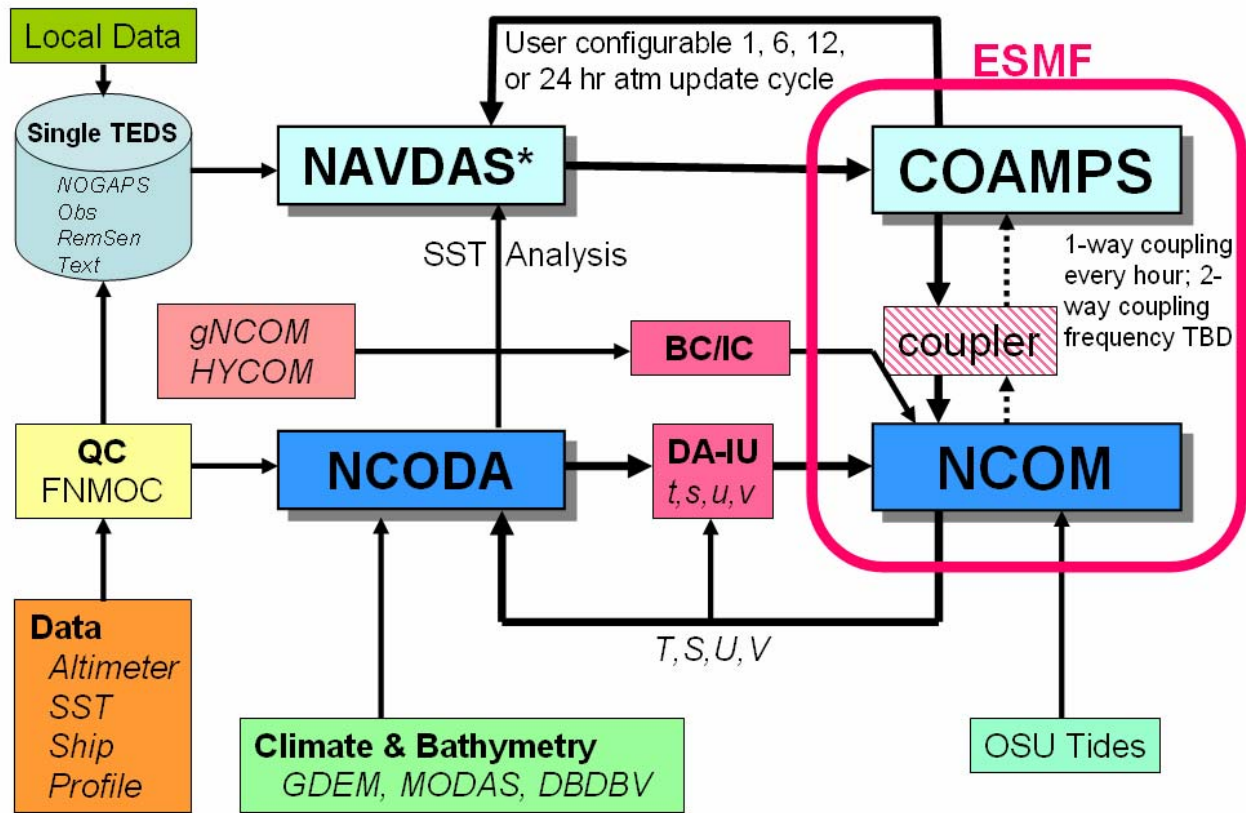
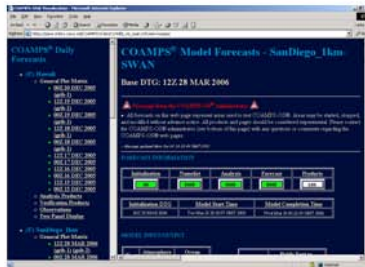***Figure 1** Overview of coupled atmosphere-ocean prediction system being developed under this project.*

COAMPS-OS® on the NSW/RTP Cluster

• 4 meshes, 45/15/5/1.67-km resolution

• 48-hour forecast, hourly nowcast

• Run twice each day (00Z/12Z basetimes)

• 16 computational processors

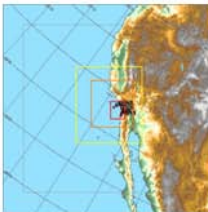• Requires ~3.5 hours to complete
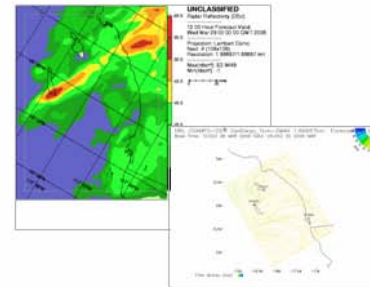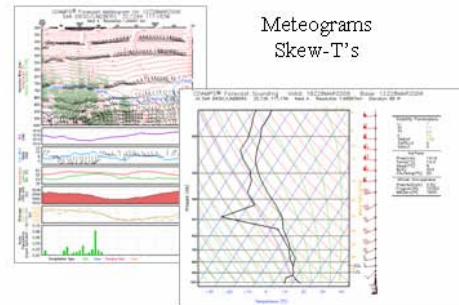
2D Graphics

COAMPS-OS Homepage

1.67-km domain

45-km domain

Meteograms Skew-T's

GRIB Files

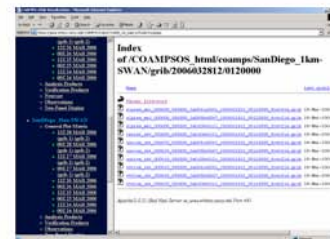COAMPS® and COAMPS-OS® are registered trademarks of the Naval Research Laboratory.

Figure 2. Example of the types of atmospheric products available with the COAMPS-OS system for the southern California area.
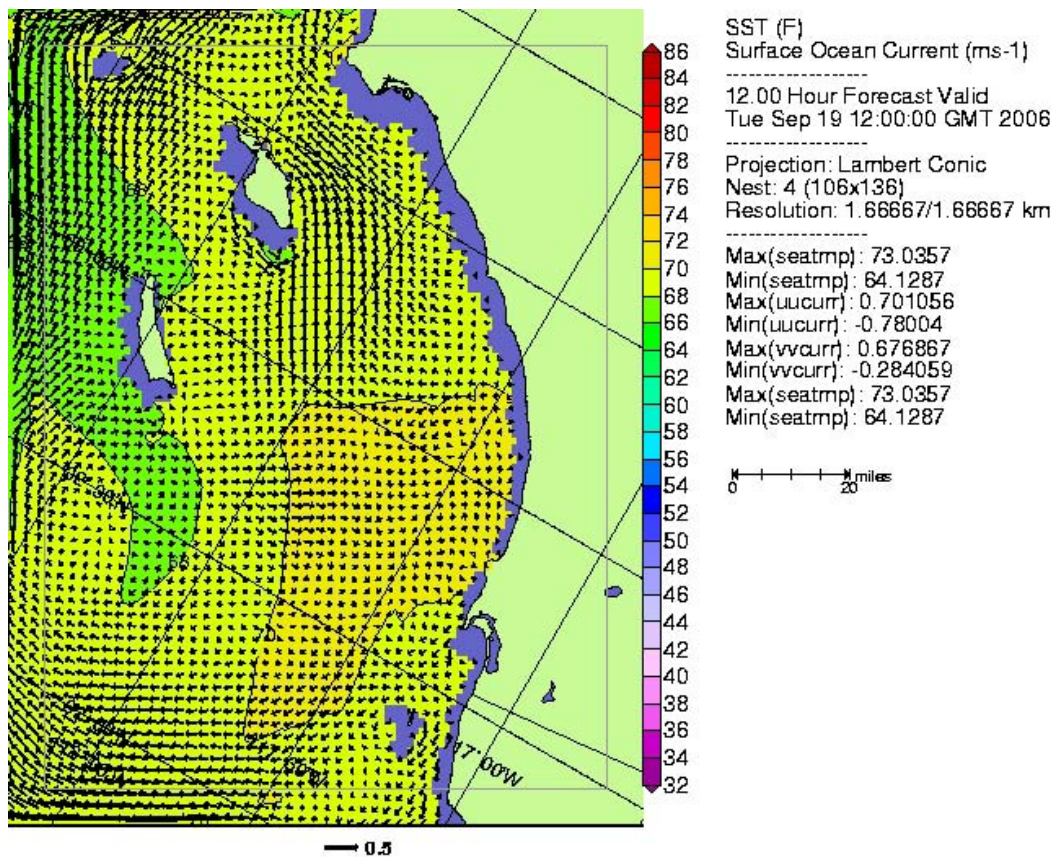
Figure 3. NCOM sea surface temperature with surface currents overlaid for September 19, 2006. Model resolution is 1.7 km and atmospheric forcing from the 1.7 km inner-most nest of COAMPS is used to force NCOM. Boundary conditions are provided by global NCOM.